MPI Requirements of the Network Layer

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Community feedback assembled
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Quick MPI overview

- High-level abstraction API
  - No concept of a connection
- All communication:
  - Is reliable
  - Has some ordering rules
  - Is comprised of typed messages
- Peer address is (communicator, integer) tuple
  - I.e., virtualized
  - Specifies a ***process***, not a ***server / network endpoint***

Quick MPI overview

- Communication modes
  - Blocking and non-blocking (polled completion)
  - Point-to-point: two-sided and one-sided
  - Collective operations: broadcast, scatter, reduce, …etc.
  - …and others, but those are the big ones
- Async. progression is required/strongly desired
- Message buffers are provided by the application
  - They are not “special” (e.g., registered)

Quick MPI overview

- MPI specification
  - Governed by the MPI Forum standards body
  - Currently at MPI-3.0
- MPI implementations
  - Software + hardware implementation of the spec
  - Some are open source, some are closed source
  - Generally don't care about interoperability (e.g., wire protocols)

MPI is a large community

- Community feedback represents union of:
  - Different viewpoints
  - Different MPI implementations
  - Different hardware perspectives
- …and not all agree with each other
- For example…

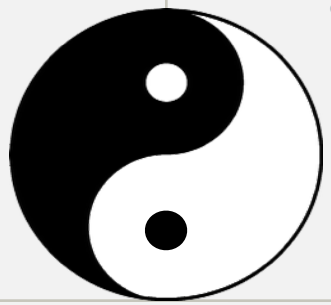
Different MPI camps

Those who want high level interfaces

- Do not want to see memory registration
- Want tag matching
  - E.g., PSM
  - Trust the network layer to do everything well under the covers

Those who want low level interfaces

- Want to have good memory registration infrastructure
- Want direct access to hardware capabilities
  - Want to fully implement MPI interfaces themselves
  - Or, the MPI implementers are the kernel / firmware /hardware developers



Be careful what you ask for…

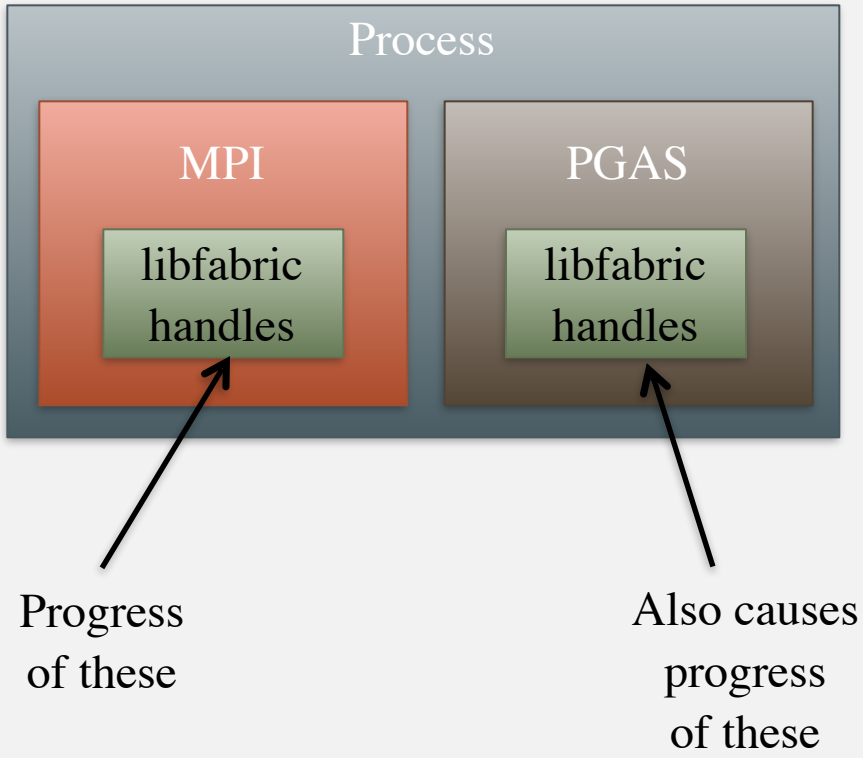
- …because you just got it
- Members of the MPI Forum would like to be involved in the libfabric design on an ongoing basis
- Can we get an MPI libfabric listserv?

Basic things MPI needs

- Messages (not streams)
- Efficient API
  - Allow for low latency / high bandwidth
  - Low number of instructions in the critical path
  - Enable “zero copy”
- Separation of local action initiation and completion
- One-sided (including atomics and shared locks) and two-sided semantics
- No requirement for communication buffer alignment (!!!)

Basic things MPI needs

- Asynchronous progress independent of API calls
  - Including asynchronous progress from multiple consumers (e.g., MPI and PGAS in the same process)
  - Preferably via dedicated hardware



Basic things MPI needs

- Scalable communications with millions of peers
  - With both one-sided and two-sided semantics
  - Think of MPI as a fully-connected model
    (even though it usually isn't implemented that way)
  - Today, runs with 3 million MPI ***processes*** in a job

Things MPI likes in verbs

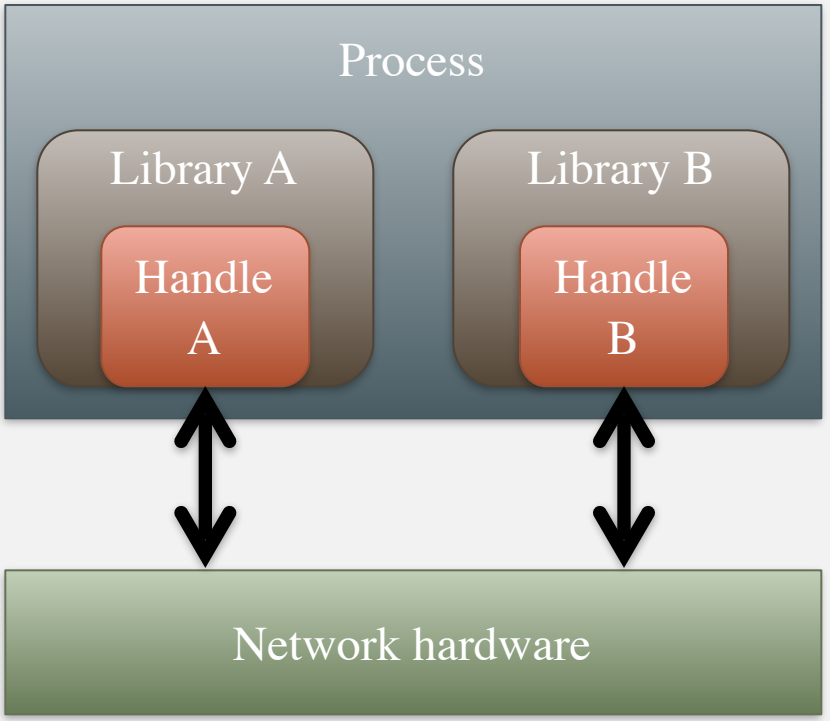
- (all the basic needs from previous slide)
- Different modes of communication
  - Reliable vs. unreliable
  - Scalable connectionless communications (i.e., UD)
- Specify peer read/write address (i.e., RDMA)
- RDMA write with immediate (*)
  - *…but we want more (more on this later)*

Things MPI likes in verbs

- Ability to re-use (short/inline) buffers immediately
- Polling and OS-native/fd-based blocking QP modes
- Discover devices, ports, and their capabilities (*)
  - *…but let's not tie this to a specific hardware model*
- Scatter / gather lists for sends
- Atomic operations (*)
  - *…but we want more (more on this later)*

Things MPI likes in verbs

- Can have multiple consumers in a single process
  - API handles are independent of each other



Things MPI likes in verbs

- Verbs does not:
  - Require collective initialization across multiple processes
  - Require peers to have the same process image
  - Restrict completion order vs. delivery order
  - Restrict source/target address region (stack, data, heap)
  - Require a specific wire protocol (*)
    - *…but it does impose limitations, e.g., 40-byte GRH UD header*

Things MPI likes in verbs

- Ability to connect to “unrelated” peers
- Cannot access peer (memory) without permission
- Ability to block while waiting for completion
  - *...assumedly without consuming host CPU cycles*
- Cleans up everything upon process termination
  - E.g., kernel and hardware resources are released

Other things MPI wants (described as verbs improvements)

- MTU is an int (not an enum)
- Specify timeouts to connection requests
  - *…or have a CM that completes connections asynchronously*
- All operations need to be non-blocking, including:
  - Address handle creation
  - Communication setup / teardown
  - Memory registration / deregistration

Other things MPI wants (described as verbs improvements)

- Specify buffer/length as function parameters
  - Specified as struct requires extra memory accesses
  - *…more on this later*
- Ability to query how many credits currently available in a QP
  - To support actions that consume more than one credit
- Remove concept of "queue pair"
  - Have standalone send channels and receive channels

Other things MPI wants (described as verbs improvements)

- Completion at target for an RDMA write
- Have ability to query if loopback communication is supported
- Clearly delineate what functionality *must* be supported vs. what is optional
  - Example: MPI provides (almost) the same functionality everywhere, regardless of hardware / platform
  - Verbs functionality is wildly different for each provider

Other things MPI wants (described as verbs improvements)

- Better ability to determine causes of errors
- In verbs:
  - Different providers have different (proprietary) interpretations of various error codes
  - Difficult to find out why ibv_post_send() or ibv_poll_cq() failed, for example
- Perhaps a better strerr() type of functionality (that can also obtain provider-specific strings)?

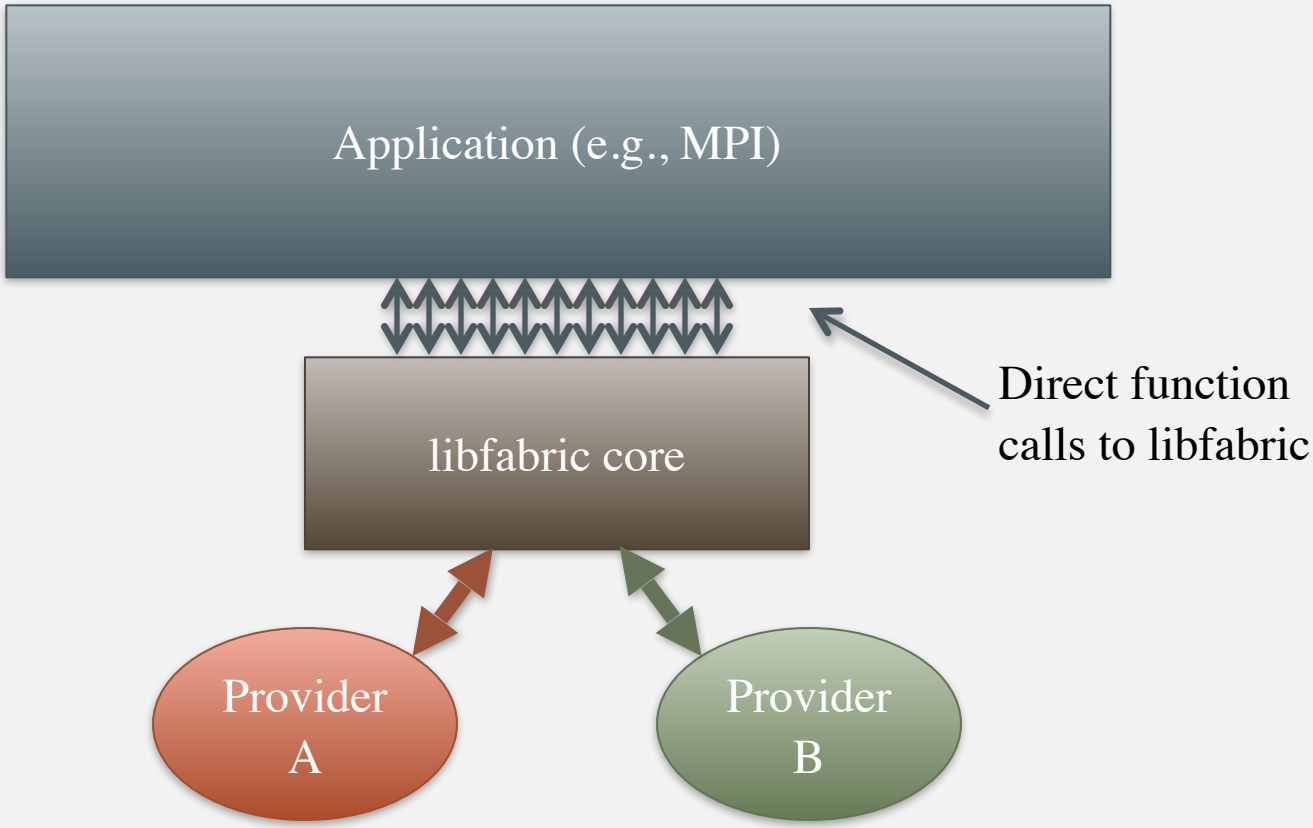
Other things MPI wants: Standardized high-level interfaces

- Examples:
  - Tag matching
  - MPI non-blocking collective operations (TBD)
  - Remote atomic operations
  - …etc.
  - *The MPI community wants input in the design of these interfaces*
- Divided opinions from MPI community:
  - Providers must support these interfaces, even if emulated
  - Run-time query to see which interfaces are supported

Other things MPI wants: Vendor-specific interfaces

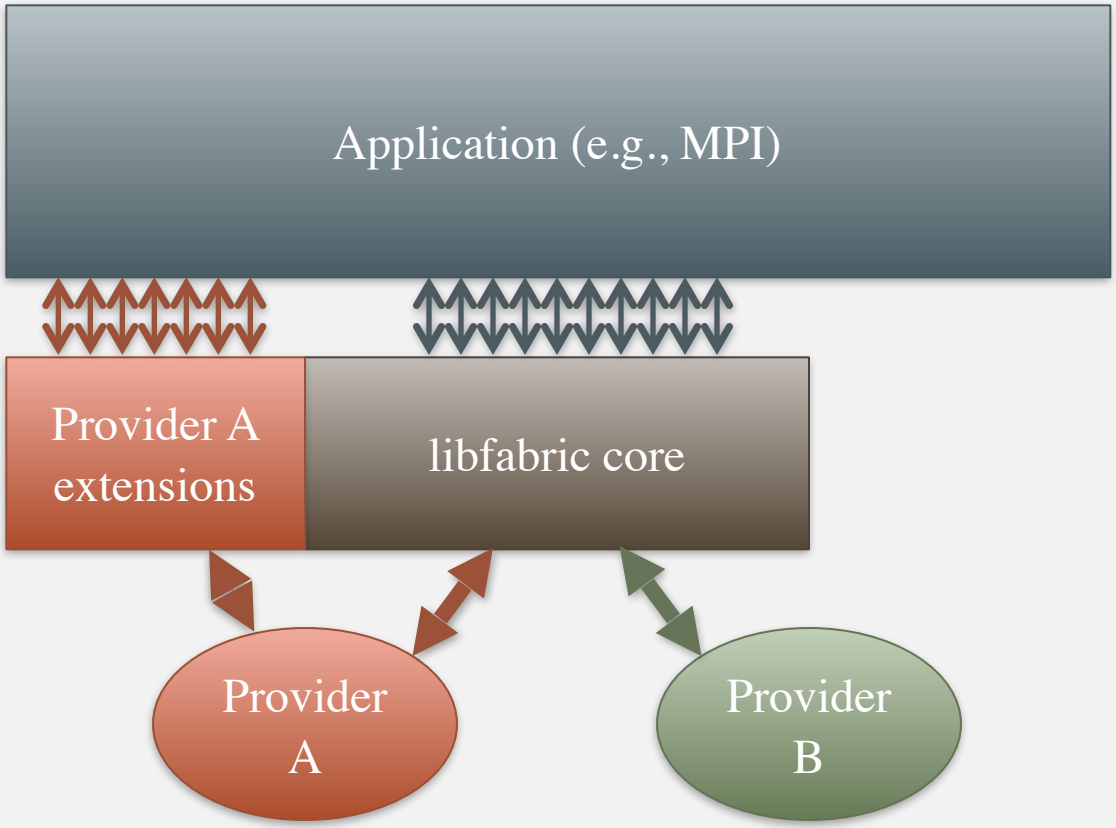
- Direct access to vendor-specific features
  - *Lowest-common denominator API is not always enough*
  - Allow all providers to *extend* all parts of the API
- Implies:
  - Robust API to query what devices and providers are available at run-time (and their various versions, etc.)
  - Compile-time conventions and protections to allow for safe non-portable codes
- *This is a radical difference from verbs*

Core libfabric functionality

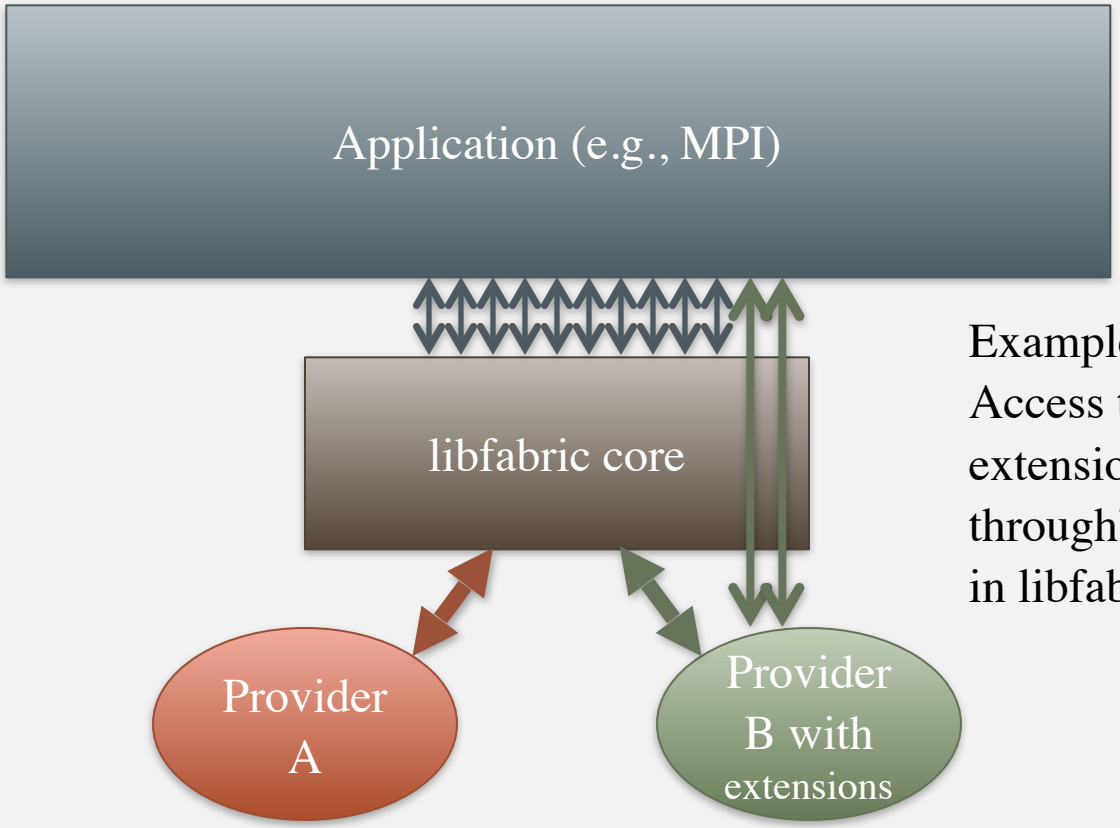


Example options for direct access to vendor-specific functionality

Example 1: Access to provider A extensions without going through libfabric core



Example options for direct access to vendor-specific functionality



Example 2:
Access to provider B extensions via "pass through" functionality in libfabric

Other things MPI wants: Regarding memory registration

- Run-time query: is memory registration is necessary?
  - I.e., explicit or implicit memory registration
- If explicit
  - Need robust notification of involuntary memory de-registration (e.g., munmap)
- If the cost of de/registration were “free”, much of this debate would go away ☺

Other things MPI wants: Regarding fork() behavior

- In child:
  - All memory is accessible (no side effects)
  - Network handles are stale / unusable
  - Can re-initialize network API (i.e., get new handles)
- In parent:
  - All memory is accessible
  - Network layer is still fully usable
  - Independent of child process effects

Other things MPI wants

- If network header knowledge is required:
  - Provide a run-time query
  - Do not mandate a specific network header
  - E.g., incoming verbs datagrams require a GRH header
- Request ordered vs. unordered delivery
  - Potentially by traffic type (e.g., send/receive vs. RDMA)
- Completions on both sides of a remote write

Other things MPI wants

- Allow listeners to request a specific network address
  - Similar to TCP sockets asking for a specific port
- Allow receiver providers to consume buffering directly related to the size of incoming messages
  - Example: “slab” buffering schemes

Other things MPI wants

- Generic completion types. Example:
  - Aggregate completions
  - Vendor-specific events
- Out-of-band messaging

Other things MPI wants

- Noncontiguous sends, receives, and RDMA opns.
- Page size irrelevance
  - Send / receive from memory, regardless of page size
- Access to underlying performance counters
  - For MPI implementers and MPI-3 “MPI_T” tools
- Set / get network quality of service

Other things MPI wants: More atomic operations

- Datatypes (minimum): int64_t, uint64_t, int32_t, uint32_t
  - Would be *great*: all C types (to include double complex)
  - Would be *ok*: all <stdint.h> types
  - Don't require more than natural C alignment
- Operations (minimum)
  - accumulate, fetch-and-accumulate, swap, compare-and-swap
- Accumulate operators (minimum)
  - add, subtract, or, xor, and, min, max
- Run-time query: are these atomics coherent with the host?
  - If support both, have ability to request one or the other

Other things MPI wants: MPI RMA requirements

- Offset-based communication (not address-based)
  - Performance improvement: potentially reduces cache misses associated with offset-to-address lookup
- Programmatic support to discover if VA based RMA performs worse/better than offset based
  - Both models could be available in the API
  - But not required to be supported simultaneously
- Aggregate completions for MPI Put/Get operations
  - Per endpoint
  - Per memory region

Other things MPI wants: MPI RMA requirements

- Ability to specify remote keys when registering
  - Improves MPI collective memory window allocation scalability
- Ability to specify arbitrary-sized atomic ops
  - Run-time query supported size
- Ability to specify/query ordering and ordering limits of atomics
  - Ordering mode: rar, raw, war and waw
  - Example: “rar” – reads after reads are ordered

“New,” but becoming important

- Network topology discovery and awareness
  - …but this is (somewhat) a New Thing
  - Not much commonality across MPI implementations
- Would be nice to see some aspect of libfabric provide fabric topology and other/meta information
  - Need read-only access for regular users

API design considerations

- With no tag matching, MPI frequently sends / receives two buffers
  - (header + payload)
  - Optimize for that
- MPI sometimes needs thread safety, sometimes not
  - May need both in a single process
- Support for checkpoint/restart is desirable
  - Make it safe to close stale handles, reclaim resources

API design considerations

- Do not assume:
  - Max size of any transfer (e.g., inline)
  - The memory translation unit is in network hardware
  - All communication buffers are in main RAM
  - Onload / offload, but allow for both
  - API handles refer to unique hardware resources
- Be “as reliable as sockets” (e.g., if a peer disappears)
  - Have well-defined failure semantics
  - Have ability to reclaim resources on failure

Conclusions

- Many different requirements
  - High-level, low-level, and vendor-specific interfaces
- The MPI community would like to continue to collaborate
  - Tag matching is well-understood, but agreeing on a common set of interfaces for them will take work
  - Creating other high-level MPI-friendly interfaces (e.g., for collectives) will take additional work

Thank you!